Chandra Observation of the Intermediate-mass Young Star MWC297

Kenji Hamaguchi[a], Shigeo Yamauchi[b] & Katsuji Koyama[c]

[a] NASA / Goddard Space Flight Center / Laboratory for High Energy Astrophysics

E-mail: kenji@milkyway.gsfc.nasa.gov

[b] Iwate University, Japan, [c] Kyoto University, Japan

Abstract

We observed a star forming field which contains the intermediate-mass young Herbig Ae/Be (HAeBe) star MWC297 using the ACIS instrument on the *Chandra* X-ray Observatory. In our 37 ksec observation we detect 18 X-ray sources above 4σ within the 9'x17' ACIS field of view. Most sources are positionally correlated with *J*, *K* and *H* band sources detected in the 2MASS survey. The detected sources have net photon counts of between 10-100 counts. Six sources with more than 30 counts have large absorption columns of 1-6 $\times 10^{22}$ cm^{-2} and plasma temperatures approaching ~2 keV. The other weak sources are at least as hard as the six brightest sources, suggesting that all the detected sources are deeply embedded.

MWC297 exhibited a large X-ray flare reminiscent of low-mass stellar flares during an earlier *ASCA* observation (Hamaguchi et al. 2000). Identifying the flaring source with *Chandra*'s pin-point spatial resolution is important to address whether HAeBes have magnetic activity similar to low-mass stars. *Chandra* detected an X-ray source at the position of MWC297, but the flux is a hundred times smaller than that expected from the *ASCA* observation. Assuming N_H ~2x10^{22} ergs s^{-1} converted from its A_V, the X-ray luminosity is only 2x10^{29} ergs s^{-1}, corresponding to log L_X/L_{bol} ~ -8.8. This ratio is quite small when compared with other HAeBe stars (which have log L_X/L_{bol} ~-4- -6) and even with normal OB stars driven by wind shocks (~ -6-- -8). We discuss reasons for the small X-ray luminosity.

Introduction

The *ROSAT* and *ASCA* satellites have detected X-ray emission from intermediate-mass pre-main-sequence stars called Herbig Ae/Be (HAeBe) stars(Zinnecker & Pribisch 1994; Skinner & Yamauchi 1996; Yamauchi et al. 1998; Hamaguchi et al. 2000; Hamaguchi 2001). The X-ray luminosity does not have clear correlation with stellar physical parameters such as spectral type and mass loss rate. In the standard theory of stellar evolution, they are not thought to have X-ray emission mechanism that ordinary stars have: magnetic activity on the stellar surface (low-mass stars) and wind activity induced by strong UV acceleration (OB stars). The emission mechanism is not well understood.

In the *ASCA* observations, we found a large X-ray flare from the Herbig Be star MWC297 (Hamaguchi et al. 2000; Figure 1). This event might prove that HAeBe stars drive magnetic activity. We performed a Chandra observation of the MWC297 field to pin-point the flare source with subarcsec spatial resolution.

MWC297 [18:27:39.6, -3:49:52 (J2000)]

- A mildly embedded star (A_V~8) in the Aquila Rift
- Spectral Type - B0-B3, Distance ~250pc
- Pre-main-sequence (Herbig Be star) or zero age main-sequence (ZAMS) star

(Ref: Hillenbrand 1992; Drew et al. 1997; Cidale et al. 2001; Benedettini et al. 2001)

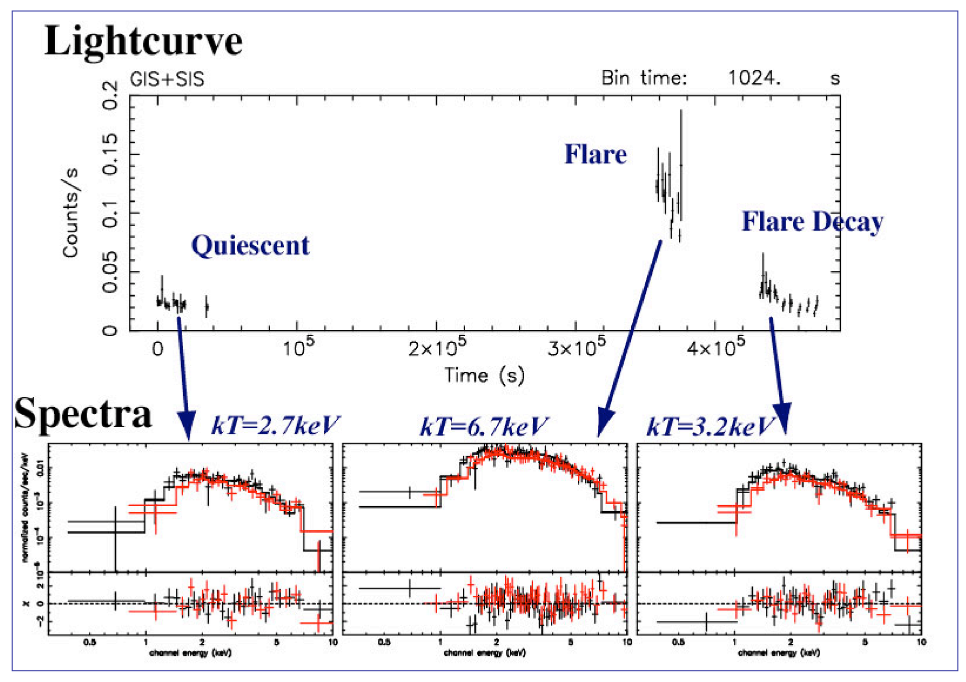

Figure 1. An X-ray flare observed at the position of MWC297 during the ASCA observations in Apr. 1994 (Hamaguchi et al. 2000). The upper panel shows the light curves in the full energy band, merging the SIS (CCD camera: 0.4-10keV) to the GIS (gas counter: 0.8-10keV) data. The vertical axis shows detector count rate. The flux is constant in the first observation (quiescent state), increases by a factor of 5 in the second observation (flare state) and gradually decreases exponentially to nearly the same flux as the pre-flare level at the end of the third observation (flare decay state). The lower panel shows spectra of each observation, fit by an absorbed thin-thermal plasma model (MekaL code). Red color shows the SIS data and black shows GIS data. Solid lines show best-fit models. The plasma temperature in the quiescent phase of 2.7keV increased to 6.7keV at the flare and decreased to 3.2keV.

The time variation and plasma heating seen during the flare is reminiscent of flares on low-mass stars and the sun, which suggests the flare is driven by some kind of magnetic activity.

Chandra Observation

Date: September 21, 2001

Exposure: 37.3 ksec

Detector: CCD camera array, ACIS-I (9'x17') & ACIS-S 2, 3. Half window option.

Result

- 18 Sources are detected between 0.5-9keV above 4σ (Figure 2).
  - Total photon counts of the detected sources are quite small (<60 cts).
  - A weak source (Src 9) is detected at the position of MWC297.
  - 70% of the detected sources have *K* band counterparts on the 2MASS image (Figure 2 right panel).
- Light curves of the detected sources do not show significant time variability within the limited statistics.
- Spectra of five relatively bright sources can be reproduced with an absorbed thermal (MekaL) model with abundance of 0.3 solar.
  - N_H ~ 1-6x10^{22} cm^{-2}, *k*T ~ 1-2 keV

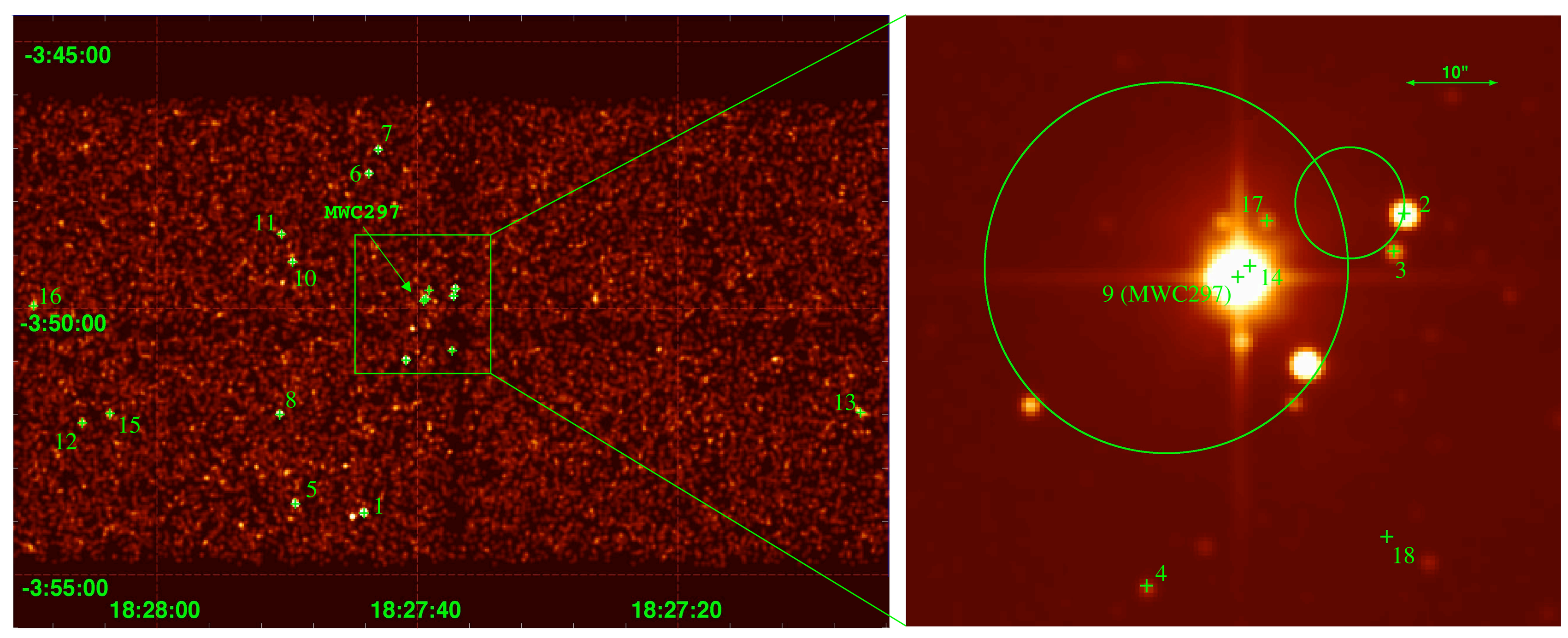

Figure 2. *Chandra* ACIS-I image of the MWC297 field in the 0.5-10keV band (*left*) and 2MASS K-band image magnified around MWC297 (*right*). Green crosses are X-ray source positions. In the right panel, the 12"(*right*) and 40"(*left*) circles are 90% error circles of the flare source positions estimated by the original (left 40" error circle: Hamaguchi et al. 2000) and the new (right 12" error circle: Gotthelf et al. 2000; Hamaguchi 2001) methods, respectively.

Discussion

Which is the Flare Source During the ASCA Observation?

Candidates (see Figure 2 right panel, Table)

- Src 9, 14 & 17, which are within the error circle estimated by the original method.
  - Extremely small flux compared with the flare source in the quiescent phase, but long time X-ray variation of stars is up to a factor of 20-30 (e.g. WL6 in ρ Oph cloud, Kamata et al. 1997; Imanishi et al. 2001) as far as we are aware. They may not be the counterpart.
- Src 2 & 3, which are just outside the error circle estimated by the new method
  - Src 2 is the brightest source among the candidates, but the N_H is significantly higher than the flare source, and it might not be the counterpart.
  - Src 3 seems to satisfy the condition of the flare source, and might be the counterpart though the X-ray flux variation should be very large (a factor of ~35).

How is the X-ray property of MWC297 (Src 9)?

The total photon counts are too small to fit the spectrum with both N_H and *k*T free. We therefore fix one parameter like.

1. N_H is fixed at the A_V converted value (1-2x10^{22}cm^{-2}: close to the condition of case1 in Table)
   - log L_X/L_{bol} ~ -9 is one order smaller than that of main-sequence OB stars (-6 ~ -8).
   - MWC297 would be B0-3, enough to drive UV wind acceleration.
   - => X-ray emission driven by wind activity should be suppressed.
2. *k*T is fixed at the typical temperature of main-sequence OB star (0.5 keV: case2)
   - log L_X/L_{bol} ~ -7.7: typical value of main-sequence OB stars.
   - N_H ~ 4x10^{22}cm^{-2} is a factor of two larger than the A_V converted value.
   - => Gas dust ratio should be different around MWC297.

Are the detected sources clustering members of MWC297?

1. Within 100" radius from MWC297
   - There are 20 clustering members (Testi et al. 1999), among which around 8 sources are expected to emit X-rays with detectable level, assuming the X-ray luminosity function in Taurus (Neuhäuser et al. 1995).
   - => Six X-ray sources within the circle can be consistently regarded as cluster members.
2. Outside of 100" radius from MWC297
   - Completeness limit of the field of view: 8x10^{-15} ergs cm^{-2} s^{-1}.
   - Galactic Absorption ($HI+H_2$) ~ 1.6x10^{22} cm^{-2} (Dickey & Lockman 1990; Dame et al. 2001).
   - There would be around 15 X-ray sources of extragalactic origin in the field assuming the X-ray distribution in the Chandra deep field north (Brandt et al. 2001).
   - Detected X-ray sources above the completeness limit are 8, which is half of the expected. Why?
   - As a further problem, there are
     - only three sources showing consistent spectra as extragalactic source(N_H>1.6x10^{22} cm^{-2}, power-law $\Gamma\sim$1.4).
     - a few sources which seem to associate with gases around MWC297.

Table: Spectral Fitting Result

Src No.	Net Counts	Temperature	N_H	Flux	Flux/F_{ASCA} [(b)]	Log L_X [(a)]
	(counts)	(keV)	(cm^{-2})	(10^{-14} ergs s^{-1} cm^{-2})	%	(ergs s^{-1})
ASCA Quiescence	----	2.7 (2.1-4.1)	2.6 (2.0-3.3)	118	----	31.3
2	61	1.2 (0.7-2.1)	6.8 (5.4-)	8	6	31.0
3	55	2.0 (0.9-4.6)	1.3 (0.5-2.6)	3	3	29.8
9 (case 1)	22	1.6 (fix)	1.5	0.4	0.4	29.1
9 (case 2)	----	0.5 (fix)	3.8	----	----	30.4
14	14	1.6 (fix)	0.2	0.2	0.2	28.4
17	9	1.6 (fix)	3.8	0.4	0.3	29.2

Parenthesis shows 90% confidence level.

(a): Unabsorbed X-ray luminosity between 0.5-10keV assuming the distance of 250pc.

(b): Flux of theflare source in the quiescent phase.

References

Benedettini, M., Pezzuto, S., Giannini, T., Lorenzetti, D., & Nisini, B. 2001, A&A, 379, 557

Brandt, W. N., Alexander, D. M., Hornschemeier, A. E., Garmire, G. P., Schneider, D. P., Barger, A. J., Bauer, F. E., Broos, P. S., Cowie, L. L., Townsley, L. K., Burrows, D. N., Chartas, G., Feigelson, E. D., Griffiths, R. E., Nousek, J. A., & Sargent, W. L. W. 2001, AJ, 122, 2810

Cidale, L., Zorec, J., & Tringaniello, L. 2001, A&A, 368, 160

Dame, T. M., Hartmann, D., & Thaddeus, P. 2001, ApJ, 547, 792

Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215

Drew, J. E., Busfield, G., Hoare, M. G., Murdoch, K. A., Nixon, C. A., & Oudmaijer, R. D. 1997, MNRAS, 286, 538

Gotthelf, E. V., Ueda, Y., Fujimoto, R., Kii, T., & Yamaoka, K. 2000, ApJ, 543, 417

Hamaguchi K., 2001, PhD Thesis, Kyoto University

Hamaguchi, K., Terada, H., Bamba, A., & Koyama, K. 2000, ApJ, 532, 1111

Hillenbrand, L. A., Strom, S. E., Vrba, F. J., & Keene, J. 1992, ApJ, 397, 613

Imanishi, K., Koyama, K., & Tsuboi, Y. 2001, ApJ, 557, 747

Kamata, Y., Koyama, K., Tsuboi, Y., & Yamauchi, S. 1997, PASJ, 49, 461

Neuhäuser, R., Sterzik, M. F., Torres, G., &Martin, E. L. 1995, A&A, 299, L13

Skinner, S. L., & Yamauchi, S. 1996, ApJ, 471, 987

Testi, L., Palla, F., & Natta, A. 1999, A&A, 342, 515

Yamauchi, S., Hamaguchi, K., Koyama, K., & Murakami, H. 1998, PASJ, 50, 465

Zinnecker, H., & Preibisch, T. 1994, A&A, 292, 152